NANO VISION
An International Open Free Access, Peer Reviewed Research Journal
www.nano-journal.org

ISSN 2231-2579 (Print)
ISSN 2319-7633 (Online)
Abbr: Nano Vision.
2013, Vol.3(3): Pg.203-208

Physical Properties of Nano-scale Zinc Oxide Thin Films using Chemical Spray Pyrolysis Method

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Presented in First National Conference on Thin Film Science and Nano Technology (FIRST-NCTFSANT-2013) September 2-3, 2013, Rajah Serfoji Govt. College, Thanjavur, T.N.(India).

ABSTRACT

Transparent thin films of zinc oxide (ZnO) were deposited onto pre-cleaned glass substrate as the precursor solution of Zinc Acetate by using chemical spray pyrolysis method at temperatures of 300^{o}C. The optical Transmittance and Absorbance spectrum of transparent ZnO thin films was measured using UV-Visible spectrophotometer in the wavelength range of 350-900nm. Developed thin films are transparent in visible region and ultra-violet cut-off wavelength almost 450nm. Developed ZnO thin films crystal structure and orientation were analyzed using X-ray Diffraction method. It revealed the developed thin films are polycrystalline nature and grain sizes almost 100nm.Thin film surface topography and morphology were analyzed using SEM (Scanning Electron microscope). The developed thin films are almost uniform particle size distributions. The developed thin films could be use as a Gas sensing and Photo voltaic applications.

Keywords: ZnO, Thin film, Spray pyrolysis, Zinc acetate, optical transmittance, topography, crystal structure, UV-Visible spectrophotometer, X-ray diffraction, SEM, Gas sensing.

INTRODUCTION

Zinc oxide is a versatile material with good electrical and optical properties, thermal and chemical stability is abundant in nature, low-cost and non-toxic. Due to this versatility ZnO has drawn considerable attention and has been investigated in various forms such as single crystals, sintered pellets, thick films, nano belts and thin films[2–14]. The thin films of ZnO find a multitude of immensely important

applications in electronic and optoelectronic devices such as transparent conductors, gas sensors, solar cell windows, surface acoustic wave (SAW) devices, heat mirrors etc.[2–10]. It is also being considered as a potential candidate in the new frontiers of research like spintronics[11]. The manufacture of zinc oxide in a form of piezoelectric transducers, varistors, phosphorescent substances, transparent conductive films, transistors TFT (thin film transistors) or gas sensors has been also reported[23-25]. Zinc oxide resists better than Si or GaAs to radiation damage so its potential application in space is possible[1]. For the vast majority of applications ZnO is used in a form of thin films. Such films can be prepared by various deposition techniques. It could be chemical vapor deposition[15], spray pyrolysis[16,17], spin-coating[18], dip-coating[19], magnetron sputtering[20], pulsed laser deposition (PLD)[21] or molecular beam epitaxy (MBE)[22]. Chemical Spray pyrolysis is one of the best depositions method in semiconductor thin films because it is easy to operate, simple technique, moderate substrate temperatures, low cost for operation and the possibility of small and large scale thin films fabrication. Thin films can be developed different vacuum pressure such as medium-low or atmospheric pressure. In this research work, we were used chemical spray pyrolysis as the thin films deposition method. Final thin films was examined and studied such as Crystal structure, Surface topography and morphology, optical properties of ZnO thin films.

EXPERIMENTAL PROCEDURE:

The films of ZnO were deposited on glass substrates by chemical spray pyrolysis technique. It is a very simple and relatively cost-effective method for preparing films of any desired composition under controlled conditions, involving the spraying of a solution containing a soluble salt of the cation of interest onto a heated substrate. The details of film deposition has been reported elsewhere[26,27]. In this research work, ZnO thin films were deposited onto pre-cleaned glass substrates by spray pyrolysis method at 300^o C substrate temperature. The substrate temperature was very important parameter influencing the thin film physical properties. To obtain good quality ZnO thin films, suitable for gas-sensing studies, the optimized value of substrate temperature was found to be 300°C. The substrate temperature should be maintained at constant value of (300 ± 5)$^{\circ}$C. All thin films with substrate having the size of 2 cm ×1 cm. 0.05 M Zinc Acetate solutions were diluted in 50ml of distilled water. It is used for all type of thin films. The detailed explanation of the spray system is given in[26,27]. During the deposition, flow-rate of the solution was kept constant at 3 ml/min, and the Spray nozzle to substrate distance was 25 cm. In the starting of each deposition process the reactor was completely exhausted and then the controlled flow rate of air was introduced into the reactor.

Table 1

Spray parameter	Value
Solution of Zinc Acetate concentration	0.05 M
Distance between Nozzle and Substrate	25 cm
Flow rate of the solution	3 ml/min
Pressure of gas	2 kg/cm2
Substrate temperature	300 ± 5^o C
Deposition time	45 min

The aqueous solution of Zinc Acetate gets thermally decomposes when following over the surface of preheated glass substrates. Finally ZnO thin film having the well adherent and uniform particle distribution. Deposited films of ZnO are good transparent with dim white shade.

The chemical reaction was as follows:

$Zn(CH_3COO)_2 .2H_2O_{(aq)} \rightarrow ZnO_{(s)} + CH_3COCH_{3(g)} + CO_{2(g)} + 2H_2O_{(g)}$

Thin films surface topography and morphology were studied using TESCAN VEGA3 LMU model SEM. The wavelength range of the absorption spectra of the thin films was recorded from 350 nm to 900 nm by UV–VIS spectrophotometer.

RESULTS AND DISCUSSION

The crystal structure of the thin films was analyzed and recording using X-Ray Diffractometer (PANalytical X'Pert) with CuKα radiation having the wavelength of 1.54056°A at room temperature in Fig. 1. The intensity data were collected over a range 2θ is from 10 to 80°. The plots are between the intensity (in arbitrary unit) and 2θ. Strong preferential growth is observed along (002) plane indicating that the films are oriented along c-axis[31]. The result indicates that the films have a polycrystalline structure with (1 0 0), (0 0 2), (1 0 1) and (1 0 2) orientation. The average sizes of crystallites (D) were calculated using the Scherrer formula[28],

$$D = k\lambda/\beta \cos \theta$$

Where k is a constant and in k = 0.9, λ is the wavelength of the incident X-ray (λ = 1.54056°A), β2θ is the full width at half maximum of (0 0 2) peak of XRD pattern, Bragg angle, 2θ, is around 35.74°. The crystallite size of peak (0 0 2) plane is 111 nm was calculated for ZnO thin films, respectively. The evaluated structural parameters of thin films are presented in Table 2.

Table 2. Structural parameters of ZnO thin films

Planes	Pos. [°2Th.]	FWHM [°2Th.]	d-spacing [Å]	Grain size D (nm)
(100)	29.1313	0.0773	3.06328	210
(002)	35.7428	0.1477	2.51034	111
(101)	38.8421	0.1155	2.31687	144
(102)	49.4211	0.2234	1.84283	77

Transmittance of the prepared transparent thin films was analyzed at room temperature by UV Vis spectrophotometer in the wavelength range of 350 to 900 nm. In figure 2, 95 % transparency in the visible range of wavelength is demonstrated. The spectral cut-off was observed at approximately 350 nm, which is consistent with other studies[29,30]. Thin films cross-sectional Topography and Morphology were

analyzed using TESCAN VEGA3LMU Scanning Electron Microscope (SEM) as shown figure 3. The samples were coated with a thin layer of gold film by

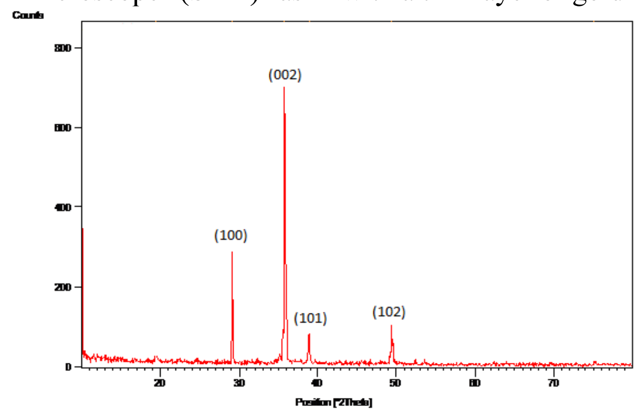

Figure 1. XRD pattern of ZnO thin film

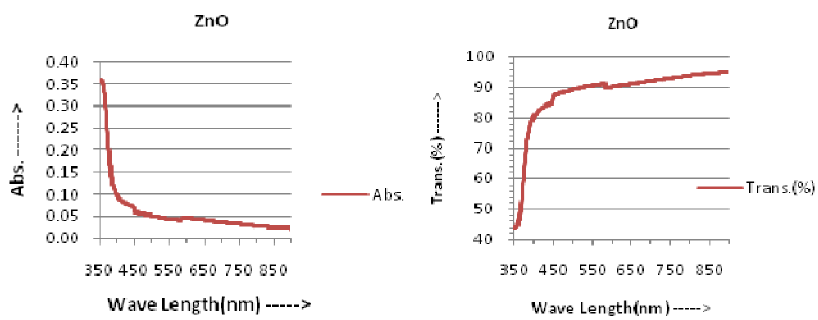

Figure 2. Transmission and Absorbance spectrum of ZnO thin films

Sputter coater to avoid charging for SEM imaging. Moreover it clearly evidences that each grain is made up with an agglomeration of (nanometer size) very small crystallites.

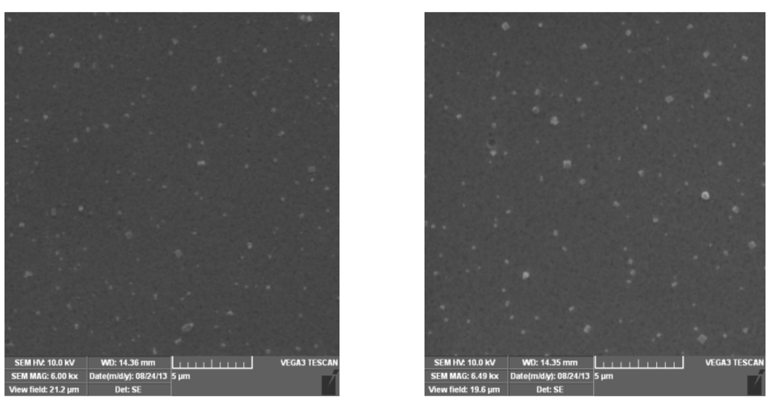

Figure 3. SEM images of ZnO thin films

CONCLUSIONS

Nano scale Zinc Oxide thin films were effectively deposited onto pre-cleaned glass substrates by chemical spray pyrolysis method. The deposition parameters were optimized to have high-quality crystalline thin films. These films were optically transparent, adherent and uniform particle distribution. These annealing films were characterized using XRD and it revealed poly-crystalline in nature and also crystal size was 111 nm. SEM studies confirmed that the ZnO films have uniform distribution and well grown crystalline morphology. This film was well transparent in the visible region; with an average optical transmittance of 95%. These thin films can be used for Gas sensing and Photo voltaic applications.

ACKNOWLEDGEMENTS

One of the authors, R.Ramadas would like to thank DST-Nanomission, New Delhi, Govt. of India for providing fund for our research at the Division of Nanotechnology of Periyar Maniammai University, Thanjavur, Tamilnadu, India.

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